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BIOLOGICAL BULLETIN

A SIGNIFICANT CASE OF HERMAPHRODITISM IN FISH.[1]

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The subject of hermaphroditism in fish has received the attention of only a few workers. Our principal information is derived from the work of Stephan ('01). This author describes for certain species of fish a complete and simultaneous hermaphroditism, ripe ova and spermatozoa appearing in the same individual at the same time; for other species a protandric hermaphroditism, the individuals while young being males and later in life becoming females; for still others, a precocious appearance of sexuality in the males and a tardy appearance of the latter in the females of species still considered as unisexual.

The condition last mentioned is interpreted by Roule ('02), on the basis of rather doubtful evidence, as a true case of protandric hermaphroditism. He measured large numbers of sexually mature individuals belonging to several species of Cyprinidæ, and found that all of the individuals of small size were males and all those of large size were females. Hence, according to Roule, all individuals are males when young and females when older. The only alternative interpretation of the facts presented seems to be that these species exhibit strict unisexuality of all individuals, with dwarfing of the males and precocious appearance of male sexuality. Roule points out, however, that, on this basis, one would expect to find among the smaller individuals young females with immature sex glands, and that there should be at least as many of the latter as there are adult females. But none such were found by him.

[1] Contribution from the Zoölogical Laboratory of the University of Texas, No. 94.

Roule's paper, being simply a preliminary statement, is too inadequate to furnish the basis for a detailed discussion, yet it might be well to point out that the Pœciliidæ, a family rather closely related to the Cyprinidæ with which Roule worked and about which there can be no suspicion of normal hermaphroditism, exhibit conditions closely parallel to those cited by Roule.

Let us take, for example, the state of affairs in *Fundulus majalis*. Here the mature males are, on the average, considerably smaller than the mature females; yet the largest of the males often surpass in size the smaller sized females. Again, the very smallest sexually mature individuals are always males and the very largest are always females. The males also mature distinctly earlier in the season than do the females. All of these facts attest the precocity and dwarfing of the males.

In view of the fact, however, that in *F. majalis* there is a very pronounced sexual dimorphism that begins to make itself apparent in very young and immature fish, it becomes certain that all individuals are unisexual throughout life. The individual whose discovery gave occasion for this paper, is the only exception to this rule that has come under the observation of the writer although he has examined thousands of specimens of this and allied species during the last three years.

In order that the reader may more readily understand the account of this rather remarkable case of hermaphroditism it seems necessary to recapitulate certain facts concerning the sexual dimorphism and spawning behavior of *Fundulus majalis*, a subject treated extensively in former papers (Newman, '07 and '08).

In *F. majalis* the sexes differ in the following particulars:

1. The females are larger, on the average, than the males.

2. The body color pattern of the two sexes is entirely different; that of the male consisting of distinct transverse bands running from back of the head to near the base of the caudal fin (see Fig. 1); that of the female, on the other hand, consisting essentially of well-marked longitudinal stripes, perfect anteriorly and merging posteriorly into a few cross bands like those of the male (see Fig. 4).

3. The cross-banded pattern is the primitive one for the family as well as for the species, and all young fish of both sexes start out with this pattern. The males retain this juvenile pattern, in a somewhat strengthened form, throughout adult life. In the females, however, the primitive cross-banded pattern is gradually transformed into one characterized by longitudinal stripes, in the following manner. The cross bands, beginning with the anterior ones, show thickenings in two places. The parts of the bars between these thickened regions thin out and disappear, leaving

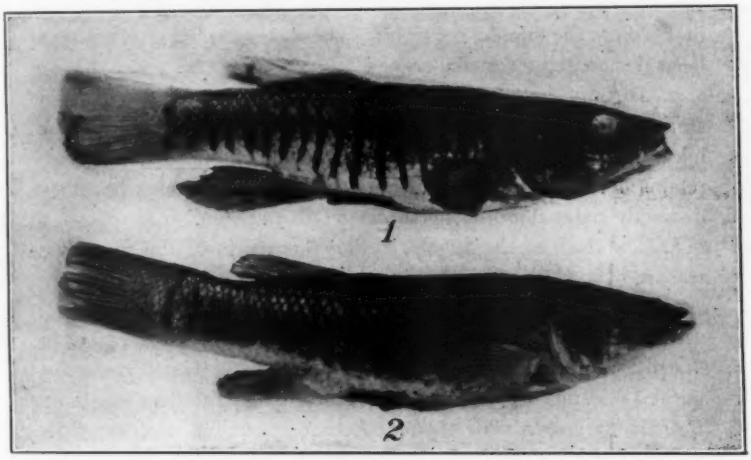

FIG. 1. Photograph of preserved specimen of male *Fundulus majalis* from the right side (slightly reduced). This specimen shows the dark spawning coloration about head and back, the large size of dorsal and anal fins, the typical cross-banded pattern. The characteristic male marking on the dorsal fin, however, shows only faintly.

FIG. 2. Photograph of the hermaphrodite specimen of *F. majalis*, taken with the same exposure as Fig. 1. Note that the general body coloration is almost that of the male, but that the cross-banded pattern is weaker. This pattern, however, was much stronger in life. In other respects it resembles the female (Fig. 4).

the thickened regions arranged in two rows. These then fuse longitudinally into two or more stripes. This process is described fully and figured in a former paper (Newman, '07).

4. The male is characterized by the presence of a very prominent dark spot or series of spots, surrounded by a light area situated on the posterior rays of the dorsal fin. The photograph

(Fig. 1) does not do this character justice. A far better idea of the prominence of this sexual marking can be obtained from an examination of the illustration in the paper just referred to.

5. The dorsal and anal fins of the male are much larger and stronger than those of the female and are used as clasping organs in spawning.

6. These fins and all parts of the body of the male that come into intimate contact with that of the female in spawning and courtship are covered with small finger-like papillæ that lend to these parts a decided roughness and undoubtedly assist the male in holding the female securely. These organs have elsewhere been designated "contact organs."

7. During the sexual climax the whole body of the male is suffused with dark pigment, some specimens showing an almost inky blackness on head, cheeks and back. The female, however, retains her normal pale olivaceous tint, or in many cases becomes distinctly paler than during the vegetative season.

8. The flesh of the female, during the height of the spawning season, becomes softer than usual and the abdomen is greatly distended with ripe ova.

9. The behavior of the males, during the spawning season, is sharply contrasted with that of the females. The former are spirited and pugnacious, and frequently follow the females about in order to spawn with them. Actual spawning, however, was observed only occasionally in *F. majalis*, but it is essentially like that of *F. heteroclitus*, which was observed hundreds of times. The behavior of the female is characteristically coy.

These and a few minor differences between the sexes will serve to render intelligible the account of the individual now to be described.

Description of the Hermaphrodite Specimen.

The fish herein described was discovered by merest chance during the progress of some breeding experiments at the Woods Hole laboratories.

On July 3, 1907, needing a male *Fundulus majalis*, I rather hurriedly dipped out of the aquarium what I took to be a large, but decidedly pale, male. Wishing to perform an experiment

with the milt of just such a male as this seemed to be, I attempted, without further examination, to strip milt from the specimen. Instead of milt a stream of eggs issued from the short genital tube at the base of the anal fin. I knew, of course, that fish frequently eat eggs and pass them undigested through the digestive tract, but such eggs are always dead and opaque, while these eggs were normally transparent. Surprised at the extrusion of eggs from an individual supposedly male I proceeded to make a careful examination. This revealed the fact that the fish was male only in one respect. It showed the cross-banded body pattern of the male very distinctly. It lacked, however, the characteristic spot on the dorsal fin, the large size of dorsal and anal fins, contact organs, and intensified pigment of the typical male; while it possessed the distended abdomen soft flesh, lighter ground color, small fins, and external oviducal tube of the spawning female. Yet I had never before seen an adult or even a juvenile female without longitudinal stripes distinctly indicated.

The specimen seemed sufficiently unusual to deserve a separate aquarium, where it was well fed and relieved of its burden of eggs several times during the ensuing fortnight. These eggs showed a rather low degree of fertility, although at least ten per cent. developed in each case.

After about a week a typically marked female of about the same size was introduced into the special aquarium for the sake of comparison, and both normal and abnormal specimens were treated alike. For nearly two weeks the two fish behaved alike, but after that time the cross-banded fish began to lose its quiet passive behavior and to assume a decidedly overbearing attitude toward its companion. Several of my fellow investigators called my attention to this curious behavior, which might well be termed "bossy." Accompanying this change in behavior were several morphological changes. The body became slimmer, as would be expected since the eggs had practically all been extruded, the flesh became harder, and dark pigment was laid down all over the body. The latter was most noticeable on head and cheeks which had become decidedly dusky, a change very characteristic of males entering upon the period of high sexual tone. The cross bands become darker and more distinct and a faint wash of orange tint appeared on the anal fin, a distinctly male character.

During the last week of July the fish was kept under close observation. On several occasions it showed a type of behavior distinctly male-like. It followed the female about and repeatedly made movements that seemed to indicate a weak attempt at spawning. Of this I could not be positive, but in other respects the behavior was that of a courting male. It would have surprised me greatly had there been an exhibition of actual spawning, for, as has been said, *F. majalis* seldom spawns in captivity.

On the last day of July the writer was compelled to leave the laboratories and the fish was killed and carefully preserved in formalin.

An examination of the formalin-preserved sex gland revealed the fact that it was a composite gland, containing about five per cent. of testicular tissue, slightly immature, and imbedded in a mass of immature and stale ovarian tissue. The testicular tissue occurred in minute lumps, principally near the posterior end of the gland. Although distinctly testicular in structure, these small masses showed a less typical structure than that of normal testis, being less compact and interspersed with connective tissue. The color, size and general appearance of the whole gland was that of a preserved testis, there being no yellow color present as is the case in normal ovaries after the close of the spawning season.

A further close examination of the body pattern showed that the cross banding on right and left sides was not equally perfect, that of the right side showing the character in as perfect a form, if less distinct, as in a typical male, that of the left being partially broken into shorter bars, the beginning of a tendency on the part of the cross-banded pattern to break up into the rows of spots that furnish the material for longitudinal stripes.

The photograph of the specimen taken from the right side shows the pattern far less distinctly than in life on account of the fact that scales and skin, rendered opaque by the preservative, obscure the underlying markings. In other respects the illustration (Fig. 2) is a faithful representation of the conditions. Photographs of the left side failed entirely to bring out the points desired, so it was necessary to insert a camera drawing as the best substitute. This drawing (Fig. 3), showing the less perfect

cross banding, when compared with the average condition seen in an adult female (Fig. 4), will show a striking contrast. It will be noted that the hermaphrodite exhibits a somewhat juvenile figure in that the head is shorter, the body broader and the tail less tapering. These points might not be patent to one not very familiar with the species.

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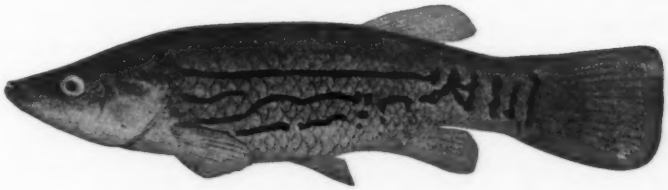

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FIG. 3. Outline camera drawing of the hermaphrodite from the left side, to show the rather broken character of the cross-banded pattern.

FIG. 4. Wash drawing, showing a typical female *F. majalis*. Many specimens show a far more complete transformation of the juvenile cross-banded pattern into the series of longitudinal stripes but few females of this size show a less advanced condition. Note the long head, comparatively small dorsal and anal fins, and comparatively light ground color of head and back.

GENERAL CONSIDERATIONS.

1. The extreme rarity of hermaphroditism in fish normally unisexual makes this case worthy of note, especially as the sexes are so well differentiated in form, color pattern, and behavior. No other case comparable with this is on record. There seems, in fact to be only one case of abnormal hermaphroditism in fish in the available literature. This is a brief description by Southwell ('02), of a hermaphrodite gland taken from a smoked her-

ring. The only point of interest for this discussion, since herrings seem to show no sexual dimorphism, is that the testicular tissue was located posterior to the ovarian tissue and overlapped the latter somewhat. This condition of the sex glands reminds one of the composite gland described in the preceding paragraphs.

2. Some light is thrown on the influence of the sexual secretions upon the secondary sexual characters. In this case the presence of a comparatively minute amount of imperfect testicular tissue has had the negative effect of inhibiting, in an individual predominantly female, the transformation of the juvenile into the female color pattern; and the positive effect of producing in this individual, at the expiration of the season's period of egg production, an approximation of male coloration and behavior.

3. In all cases of serial hermaphroditism described in available literature the hermaphroditism is protandric and in successive seasons. Here the sequence was distinctly protogynic and the changes occurred within a period of less than a month. The condition is decidedly anomalous.

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THE HOMING OF THE MUD-DAUBER.

C. H. TURNER.

INTRODUCTION.

In my paper on "The Homing of Ants"[1] there is recorded evidence that ants find the way home neither by a homing instinct nor by reflex action nor merely by kinesthetic responses; but by utilizing landmarks. In this paper I propose to record experimental evidence that the same is true of the common mud-dauber wasps.

It has long been recorded by keen observers that both the social and the solitary wasps, on leaving their nests for the first time, carefully examine the surroundings before flying away. It is also stated by some that any alteration in the immediate surroundings of the nest will render it difficult, or even impossible, for the wasp to find its way back again.

Mr. and Mrs. Peckham, who have devoted much time to the study of both the social and the solitary wasps, say:[2] "If they were furnished with an innate sense of direction they would not need to make a study of the locality of the nest in order to find the way back, but if they were without this sense it would be only common prudence to take a good account of their bearings before going far afield. . . . In reading much of the popular natural history of the day one might suppose that the insects seen flying about on a summer's day were a part of some great throng which is ever moving onward, those that are here today being replaced by a new set tomorrow. Except during certain seasons the exact opposite is true. The flying things about us abide in the same locality and are the inhabitants of a fairly restricted area. The garden in which we worked was, to a large extent, the home of a limited number of certain species of wasps that had resided there from birth or, having found the place accidentally, had settled

[1] *Jour. of Comp. Neur. and Psy.*, Vol. XVII., pp. 367–434, Pl. II.–IV.

[2] G. W. and E. G. Peckham, "On the Instincts and Habits of the Solitary Wasps," Madison, Wis., 1898, pp. 212, 213, 215.

there permanently. . . . After days passed in flying about the garden — going up Bean Street and down Onion Avenue, time and again — one would think that any formal study of the precise locality of a nest might be omitted, but it was not so with our wasps. They made repeated and detailed studies of the surroundings of their nests. Moreover, when their prey was laid down for a moment on the way home, they felt the necessity of noting the place carefully before leaving it. . . . If the examination of the objects about the nest makes no impression upon the wasp, or if it is not remembered, she ought not to be inconvenienced nor thrown off her track when weeds and stones are removed and the surface of the ground is smoothed over; but this is just what happens. *Aporus fasciatus* entirely lost her way when we broke off the leaf that covered her nest, but found it, without trouble, when the missing object was replaced. All the species of *Cerceris* were extremely annoyed if we placed any new object near their nesting-places. Our *Ammophila* refused to make use of her burrow after we had drawn some deep lines in the dust before it. The same annoyance is exhibited when there is any change made near the spot upon which the prey of the wasp, whatever it may be, is placed. We learned from experience how important it was not to disarrange the grass or plants on such occasions."

All this was written before Bethe[1] had restated, with emphasis, his theory that bees (the morphological and physiological kinship of which to wasps leads one to expect them to be psychologically similar) are guided home by an unknown force; and before Pieron[2] had asserted that ants are led home by a reflex kinesthetic sense. This being the state of affairs a crucial experiment seemed to be needed. The mud-dauber (*Sceliphron*, Klug = *Pelopœus*, Latr.) was selected, partly because its habits rendered it comparatively easy to obtain material and partly because, so far as I know, no such experiments have been performed upon it.

[1] A. Bethe, "Die Heimkehrfähigkeit der Ameisen u. Bienen zum Theil nach neuen Versuchen," *Biol. Centrlbl.*, 2 Bd. (1902), no. 7, pp. 193–215; no. 8, pp. 234–238.

[2] H. Pieron, "Du rôle sense musculaire dans l'orientation des fourmis," *Bull. Inst. Gen. Psy. Paris*, T. 4 (1904), pp. 168–187.

Preliminary Observations.

These preliminary observations were made in a laboratory the walls of which were ceiled with tongue-and-grooved pine boards. These boards were arranged vertically. Two of the walls were supplied with windows and two were not. Near the top of each of these walls mud-daubers constructed nests. Some of these nests were in dark places and some were in light places. I noticed that the wasp never flew directly to the nest, but that it would alight on a certain crack. After ascending, afoot, this crack, until it had reached the height of the nest, it would turn and walk to it. The same wasp always alighted on the same crack and at about the same distance from the floor. This led me to suppose that wasps used the cracks as landmarks. In this room a certain window was lowered from the top, through which opening the wasps came and departed. In another room, in which similar experiments were conducted, the window was raised from the bottom. Wasps frequented this room as much as they did the other. Evidently wasps can learn the way into a room by either a high or a low opening.

The Environment of the Experiments.

This series of experiments was performed in a laboratory thirty-seven and a half feet long, twenty-five feet wide and twelve feet

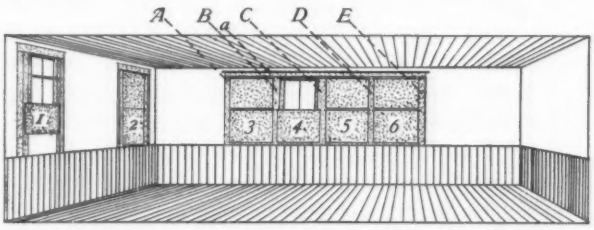

Fig. 1. This is a diagram of the room arranged for experiment one. 1–6, windows; *A–E*, upright facings of windows; *a*, location of the nest. The wood-work of the windows is shaded with broken lines, the window-shades with dots. The boards in the floor, ceiling and dado are drawn twice as wide as they were.

high (Fig. 1) which was situated in the third story of a large brick building. The ceiling was covered with tongue-and-grooved pine boards and a four-foot dado of pine ceiling extended around

the lower third of the walls of the room. Excepting the space occupied by windows, doors and dado, the walls were plastered in the rough. In the west wall there were two windows (Fig. 1, 1 and 2); in the north, four (Fig. 1, 3 to 6). The windows of the north wall were close together, being separated by wooden partitions only one foot wide (Fig. 1, *B*, *C*, *D*). Across the top of each window there was a piece of three inch moulding. On the north wall this moulding extended continuously across the four windows. There were two green blinds to each window, one to each sash. These blinds were not quite opaque. The ceiling was painted green; the walls, including dado, doors and window-facings, cream color.

In order to have only one entrance for the wasps, the lower sash of window number one was raised half way. All other windows were closed. This condition was maintained throughout the entire series of experiments. To furnish definite light relations for the beginning of the experiment, the lower shade of window number one was raised about half way and the top shades of windows one and three raised as far as possible. All the other shades were down. After these conditions had been maintained for nearly two weeks a mud-dauber began the construction of a nest on the moulding above window number three at a point about six inches from upright *B* (Fig. 1, *a*).

When first discovered the wasp had completed nearly half of one cell; hence it had already made several trips back and forth through window number one. I watched the wasp make several trips, and each time it behaved as follows. On entering the room it would fly obliquely upwards to the upper third of upright *B*. Then it would fly vertically upwards almost to the ceiling, thence it would fly leftward to the nest. The line of flight from the entrance to upright *B* was perceptibly curved, the convexity being towards the east. The flight from the entrance through window number one to the nest consumed about half a minute. In departing, the wasp flew downwards in a curve from the nest to the upper portion of the opening through which it had entered the room. After watching the wasp make several trips in practically the same manner, the following experiments were performed:

EXPERIMENT 1.

The lower shade of window number one was raised half way and the top shade as far as it would go. While the wasp was out of the room, all the blinds of windows number two to six were closed except the upper shade of window number four, which was raised as far as possible (Fig. 1).

The wasp on entering through window number one flew obliquely upwards across the beam of light from window number four to the upper third of upright *C*. (This line of flight was convex towards the east.) It then flew vertically upwards almost to the ceiling then leftward about a foot (this is a little more than the distance of the nest from upright *B*) and examined carefully the moulding. Not finding the nest, it began flying first to the right and then to the left in constantly elongating ellipses with very short minor axes. All this time it was carefully examining the moulding. Occasionally the mud-dauber would fly downward into the beam of light and then resume its search. In its lateral flights the wasp sometimes flew as far to the east as upright *D* and to the west almost as far as upright *B*. At the end of three minutes it had not found the nest, although under former conditions of illumination it required only half a minute to fly from window number one to the nest.

While the wasp was still searching for the nest, the top shade of window number four was lowered and the corresponding shade of window number three raised as far as possible. This reproduced the conditions under which the wasp had originally worked.

Almost immediately the wasp found the nest!

EXPERIMENT 2.

The lower shade of window number one was raised half way and the top shade as far as possible. While the wasp was out of doors, all the shades of windows number two to six were lowered except the top shade of window number five, which was raised as high as possible.

On entering, the wasp flew in a fairly direct line towards the nest. When about one third of the way across the room, it returned almost to window number one and described a circle of about a foot in diameter. It then flew to the middle of the upper

shade of window number four. Thence it flew upwards almost to the ceiling and then leftward to the nest.

Experiment 3.

The lower shade of window number one was raised half way and the upper shade as far as possible. All of the shades of windows number two to six were lowered except the top shade of window number three, which was raised as far as possible. This reproduced the conditions under which the wasp had worked originally.

On entering the room the wasp flew obliquely upwards to the upper third of upright *B*. Then it flew vertically upwards almost to the ceiling. Thence it flew leftward to the nest. The line of flight from the entrance to upright *B* was perceptibly curved, the convexity extending towards the east. The total flight from the entrance to the nest consumed about half a minute. The shades were maintained in the above position until the mud-dauber had made three trips. Each was made in practically the same manner.

Experiment 4.

The same conditions as in experiment one.

The behavior was practically the same as in experiment one. In this experiment, however, the shades were maintained in the same position until the wasp had found the nest, which required nearly five minutes.

The wasp was allowed to make two trips. Its behavior on the second trip resembled that on the first; but it required only three minutes to pass from the entrance to the nest.

Experiment 5.

The same conditions as in experiment three.

The wasp behaved the same as in experiment three.

Experiment 6.

The lower shade of window number one was raised half way and the top shade as high as possible. All of the shades of windows two to six were lowered, except the top shade of window number two, which was raised as far as possible.

The wasp on entering the room described a small circle then

flew obliquely upwards to a point almost to the ceiling, but a little to the west of upright *A*. It then flew alternately leftward and rightward until the nest was found, which consumed about one minute.

The wasp was allowed to make two trips. Its behavior on the second trip was similiar to that on the first, and about the same amount of time was consumed in passing from the entrance to the nest.

Experiment 7.

The conditions were the same as in experiments three and five.

The wasp was permitted to make two trips. It behaved the same as it did in experiments three and five.

Experiment 8.

The lower shade of window number one was raised half way and the top shade as high as possible. All the shades of windows two to four were lowered.

On entering the room the wasp described several small circles. It then flew first to about the middle of the upper sash of window number three, then to window number two, then to window number five. Finally, after much searching, the nest was found.

The shades were retained in the above condition until the wasp had made two trips. On the second trip it went first to upright *C* and then, after a short search, it found the nest.

Experiment 9.

The same conditions as in experiments three, five and seven.

The behavior was the same as in experiments three, five and seven. Two trips were made.

Experiment 10.

At first the conditions were the same as in experiment eight. While the wasp was on the nest, the top shade of window number one was lowered.

On leaving the nest the wasp flew away through the window in its usual way. The lowering of the top shade of window *A* did not change its behavior.

EXPERIMENT 11.

The lower shade of window number one was raised half way and the top shade lowered. While the wasp was out of doors, all the shades of windows two to six were lowered except the top shade of window three, which was raised as high as possible.

The wasp behaved the same as in experiments three, five, seven and nine.

EXPERIMENT 12.

The lower shade of window number one was raised half way. While the wasp was out of doors, all of the other shades were lowered.

The wasp behaved the same as in experiment eight.

EXPERIMENT 13.

The lower shade of window number one was raised about half way. While the wasp was out of doors, all the shades of windows two to six were lowered except the lower shade of window number three, which was raised as far as possible.

At first the wasp searched carefully the upper portion of the wall to the west of the upright *A*. Then, as a result of extending its search to the east, the nest was discovered.

This experiment was repeated with the same results.

EXPERIMENT 14.

The same conditions as in experiments three, five, seven, nine and eleven.

The wasp behaved the same as it did in experiments three, five, seven, nine and eleven.

EXPERIMENT 15.

The same conditions as in experiment one.

The wasp behaved as in experiment one. It took about one minute to find the nest. The wasp was allowed to make two trips.

EXPERIMENT 16.

The same conditions as in experiment one.

After the shades had been maintained in this position for about two days, the wasp on entering the room flew obliquely upwards

to near the top of upright *C* and then obliquely leftward and upwards to the nest. The trip from window number one to the nest consumed much less than a minute.

Experiment 17.[1]

The same conditions as in experiment three. This experiment was performed immediately after the close of experiment sixteen.

The wasp on entering the room flew obliquely upwards, across window number four, to the upper third of upright *C*; then obliquely leftward and upwards, across windows number four and three, to a little beyond the upright *A*. It then searched about until the nest was found.

The shades were left in this condition from 10:45 A. M. July 19 to 9 A. M. July 20, at which time the wasp occasionally visited the nest. The wasp on entering the room, flew obliquely upwards, across window number three, to the upper third of upright *B*; then leftward, across window number three, to a little beyond upright *A*, then obliquely rightward and upwards to the nest. The conditions in this experiment and in experiments three, five, seven, nine and eleven are identical, yet the behavior in this case is quite unlike what it was in those. Evidently prolonged exposure to the conditions described in experiment sixteen has modified the behavior of the wasp. It had lost (forgotten) its old response to the conditions described in experiment three and been forced to acquire a new response.

Conclusions.

From these experiments it is evident that, in finding its way back to its nest, the mud-dauber is guided neither by what is known as a homing instinct nor by what Pieron has called a kinesthetic reflex; for if either assumption were true, a manipulation of the light should not have altered the wasp's behavior.

Evidently light plays a prominent rôle in the homing of wasps, yet the behavior of the mud-dauber is not a phototropism; for in

[1] This series of experiments was begun on the morning of July 17, 1908, and ended on the morning of July 20, 1908. Experiments one to fifteen inclusive were performed the first day and in the order mentioned. The intervals between the experiments were only sufficiently long to permit the necessary adjustments to be made. Between experiments fifteen and sixteen there was an intermission of almost two days; between experiments sixteen and seventeen, an intermission of five minutes.

no case did the wasp so orient itself as to have the major axis of its body parallel to the rays of light. Furthermore in hunting for the nest, the wasp crossed the light sometimes in one direction and sometimes in another. In yet other cases the wasp would zigzag across the light.

Neither is the wasp's behavior merely a reflex response either to brightness or to the direction of the rays of light; for if that were the case, in experiment six, when all the shades of windows number two to four were lowered except the top shade of window number two, the wasp should have flown, not to the wall to the west of window number three, but to window number two. Likewise in experiment eight, when all the shades of windows number two to six were lowered and the only bright light entering the room was that which came through the upper and lower portions of window number one, if the wasp were guided merely by light acting reflexly, then it should not have been able to find the nest at all. Furthermore, if the wasp's behavior is merely a reflex response to light, there is no reason why it should have entered the room at all, for the open portion of the window was certainly not so bright as the window-panes from which the light was reflected. We say nothing about the bright sunshine out of doors!

But brightness is not the only factor which influences the movements of this wasp; else, when all the shades of windows number two to six were lowered, it would have been impossible for it to rediscover the nest. This series of experiments warrants the induction that, in the wasp's memory, that nest is located in a certain direction and at about a definite distance from a bright patch which is situated at a known elevation in a peculiar environment.

The above statement predicates to wasps memory and an awareness of space relations. As to the existence of memory these experiments furnish unequivocal evidence. This harmonizes with the views of Forel and the Peckhams. In "The Homing of Ants" are recorded proofs that ants have an awareness of space relations, and, since wasps are near kin to ants, it is probable that they, too, have an awareness of space relations. This series of experiments furnishes evidence to support this view. In

almost every experiment of this series the lower shade of window number one was raised half way and the top curtain all of the way. This was done in order to have the departing wasp confronted, on each trip, by an upper and a lower bright patch. Were the wasp responding to a bright patch merely and not to a bright patch in a definite place, then the wasp should have flown to the upper bright patch just about as often as it did to the lower. The wasp always flew directly from the nest to the opening in window number one! There was but one exception to this statement. On one occasion I was standing on a ladder watching the wasp construct the nest. I was within two feet of the nest. On that occasion the wasp, on departing, circled about once or twice and then returned to the nest and from there flew to the exit.

In brief, these experiments warrant the conclusion that the flying mud-dauber, like the creeping ant, is guided by certain landmarks, and that light plays a prominent rôle in furnishing such landmarks.

HAINES NORMAL SCHOOL,
AUGUSTA, GA., July 25, 1908.

EXTRUSION OF THE WINTER EGG CAPSULE IN PLANARIA SIMPLISSISSIMA.[1]

FLOYD E. CHIDESTER,

FELLOW IN ANATOMY, THE UNIVERSITY OF CHICAGO.

About the middle of October, 1907, I chanced to note that some of the *Planaria simplississima* in one of my aquaria had developed egg capsules.

I immediately transferred a number of flatworms, including those that had already formed capsules, and a few that had not as yet developed them, to a small aquarium on my desk. While examining one of the planarians and its capsule under the microscope, I saw the movements connected with the extrusion of the capsule.

When first observed, the capsule lay lengthwise of the body in the position indicated in Fig. 1.

Presently the capsule was turned by the movement of the body of the worm until it occupied a position as indicated in Fig. 2,

FIG. 1.

FIG. 2.

FIG. 3.

then slowly came to the position indicated by Fig. 3, that is, at right angles to the longitudinal axis of the body.

This change in position necessarily increased the size of the cavity in which the capsule lay, lacerating the tissue and permitting easy egress.

[1] Contributions from the Biological Laboratory, Clark University.

The planarian then moved slowly forward, the capsule passing along through its body and out at the dorsal caudad region. The rotation of the capsule in the body of the animal apparently aided in breaking the wall of the cavity in which the capsule lay, for there seemed to be no difficulty in the passage through the posterior portion of the body and out near the tail (Fig. 4).

The entire process of extrusion occupied only about thirty minutes.

The next day the wound where the capsule had originally lain was partly closed by contraction of the surrounding tissue, and the wound in the tail region made at the escape of the capsule was obliterated almost entirely.

I was interested to see if the same planarian forms more than

FIG. 4.

FIG. 5.

one egg capsule, so isolated the animal I had been observing, and examined it several times each day.

In a week complete regeneration was effected. At the end of twenty days from the time I had seen the first capsule, another appeared, evidently formed during the night, and I had the good fortune to observe its extrusion also. The movements were the same as before observed, except that the capsule was extruded on the right side of the body this time.

Other planarians bearing capsules were observed, and in all cases the capsule was rotated immediately before the extrusion

The individual described previously, at the end of about three weeks more, extruded a third capsule.

Kept in a small vial on my desk for two months after this extrusion, the planarian formed no more capsules.

The winter egg capsule of *Planaria simplississima* is a dark brown, elongated object, with a horny covering. It bears nothing so far as I could discover that would aid in holding it fast. Several capsules were opened carefully by means of sharp needles and the contents examined. There were perhaps a score of eggs and many nutritive cells.

Summary.

1. *Planaria simplississima* produces winter eggs.

2. A single individual may develop three or more capsules during the winter.

3. Complete regeneration of tissue lacerated at the extrusion of the egg capsule is effected in about one week.

4. About three weeks elapse between two successive extrusions.

LYSOROPHUS, A PERMIAN URODELE.

S. W. WILLISTON,

UNIVERSITY OF CHICAGO.

Thirty-one years ago Professor Cope described [1] briefly three small and incomplete vertebræ from the "Permian" of Vermilion County, Illinois, as those of a reptile under the name *Lysorophus tricarinatus*. The type specimen was figured, with additional descriptions, by Case in 1899.[2] In a later paper[3] Case recognized the same form from the Permian of Texas and gave a good description and figures of the vertebræ and ribs. From the peculiar coiled condition of the various intermingled series of vertebræ which he had himself collected he concluded that the animal was long and snake-like. No limb or pectoral or pelvic bones have ever been detected. Associated with the form but not definitely connected with the vertebræ was a fragment of the skull of a small animal which he doubtfully referred to the same species, but which he also was inclined to refer to *Isodectes* Cope. In 1904 Broili [4] with real skull material and less perfect vertebræ, reached the startling conclusion that the genus showed certain affinities to the fishes, because of the presence of what he thought were gular plates in the palatine region. Chiefly because of their supposed presence he proposed the family name Paterosauridæ for the genus, which he located in the Rhynchocephalia. It is needless to say that his views of the diphylectic origin of reptiles, one phylum directly from the fishes, the others from the amphibians, has been received by naturalists with doubt and incredulity, and are, as will be seen, wholly unsubstantiated by this animal. His "gular plates" were doubtless merely misplaced proatlas bones. It is rather surprising that he should have overlooked the almost impossible reptilian char-

[1] *Proc. Amer. Phil. Soc.*, 1877, p. 187.

[2] *Journal of Geology*, V., p. 714, pl. II., ff. 12*a*, 12*b*, 12*c*.

[3] *Ibid.*, May, 1892, p. 46, pl. IX., ff. 1, 2.

[4] *Paleontographica*, LI.

acters of the vertebræ and skull, characters certainly impossible for a rhynchocephalian.

Recently, in examining the material in the Chicago collections, the remarkable characters of the vertebræ, so anomalous for any reptile, and utterly unknown in this class from the Permian otherwise, aroused my interest and doubt. From the matrix containing several series of vertebræ a corner of a bone protruded which I recognized as of a mandible. Under the skilful manipulations of Mr. Paul Miller a wonderfully complete and undistorted skull was brought to light. In similar matrix, and associated with vertebræ of the same kind I recognized another mandible and several small, pitted dermal bones, probably belonging to another type of amphibian, though it is not impossible the scutes were those of *Lysorophus*.

That the present species belongs in the genus *Lysorophus* from the reputed Permian of Illinois seems tolerably well assured, though the type material of the genus is rather scanty, and not entirely sufficient to resolve doubt. That the species are identical is I believe quite improbable. With this understanding, however, it will do no harm to use Cope's name for both genus and species until such time as more and better material of the species has been obtained from the original or contemporaneous beds.

Lysorophus tricarinatus Cope.

Skull (Figs. 1–3). — The general shape of the skull is that of a four-sided pyramid, pointed anteriorly. The upper surface is nearly plane, very gently convex from side to side, and also longitudinally in front. The sutures are widely separated in the specimen, indicating a loosely joined skull, and the bones are quite smooth, without pittings or mucous canals. The nasals are relatively large bones, with nearly parallel sides, rounded anteriorly. The frontals are also four-sided, the longer sides nearly parallel; the bone is about twice as long as wide. On either side, beginning at the transversely extended fronto-parietal suture, there is a narrow bone which seems to be continuous as a single element to beyond the middle of the nasals, ending acuminately in front. This is doubtless the prefrontal of the modern urodeles. The parietals are broad and large bones, like

the frontals with nearly parallel sides, overhanging, for the most part, the open temporal region. There is no parietal foramen. They are gently convex from side to side. From this posterior suture the upper surface of the skull turns downward at an angle of about twenty degrees, so as to bring it nearly parallel with the plane of the lower margins of the mandibles. Three rather large bones are seen here, a median unpaired one and two larger lateral ones. The median bone is broader in front than behind and borders the large foramen magnum; it doubtless corresponds to the median cartilage found in many urodeles, called the supra-occipital usually, by Gaupp the tectum synoticum. The lateral

FIG. 1. *Lysorophus tricarinatus*, skull from above, enlarged three diameters.

bones are larger, of an irregularly square shape with a hook-like prolongation exteriorly behind, turned downward back of the squamosal. They must be identified as "epiotics," a bone rarely if ever found separate in the modern batrachians. The squamosal (paraquadrate of Gaupp) unites, by a nearly straight antero-posterior suture, with the parietal and epiotic and then turns downward, forward and a little outward, narrowed and more rod-like below. There is some doubt of its union with the quadrate, but the division seems apparent on each side. With this interpretation, the quadrates are small bones, about twice as

long as wide terminating in the cotylus, and perforated a little above the lower extremity by a foramen. The double occipital condyles are sessile, each with an oblique, flattened articular face looking inward and backward. Just in front of the condyles exteriorly there is a small foramen for the vagus, in front of which there is a large vacuity for the ear opening, partially or imperfectly closed in front by this combined bone. Above, the bone sends a triangular prolongation inward to the lower edge of the supraoccipital, bordering the hind margin of the epiotic. The large foramen magnum is thus bordered as in modern urodeles, nearly completely, by the exoccipital. Rather closely applied to this margin is a pair of triangular bones meeting roof-like in the middle above and terminating below in an angle a little above the condyles. They occupy the position of, and doubtless are the so-called proatlas bones, displaced to form the "gular plates" of Broili. The basioccipital bone I at first thought to be ossified, but further examination convinces me that the broken surface seen in the specimen between the condyles below is the broken off anterior end of the atlas. A like condition was found by Broili in his specimens, but he interpreted the structure as that of a broken off occipital condyle. Furthermore, a little in front of this fractured surface is seen the hind margin of a thin transverse plate, the parasphenoids.

In the palatal region are lying four pairs of branchial bones, with no indications whatever of so-called gular plates. The position and relations of these bones are well shown in the accompany ing photograph (Fig. 3). The outer pair lying close to the inner margins of the mandibles, have the posterior end thickened and recurved, hook-like, to abut against or approach the hind side of the quadrate. I would take them to be ceratobranchials save for the fact that a pair of nearly square bones very clearly articulate with the anterior ends, which must be ceratobranchials. To the inner side, and progressively more posterior, lying symmetrically, are three pairs of epibranchials the inner and hindmost represented in the specimen only by their anterior ends, the posterior portions broken off with the altas. The two outer pairs, at least, are thickened and truncate at each end, and are partly hollowed or cancellated, like all other bones of the skeleton. The first of

these pairs also seems to have a thickened and recurved posterior extremity. The mandibles are rather stout, extending a short distance back of the cotylus, expanded and flattened, somewhat spout-like in front. Each bears about twelve, conical, simple teeth on the anterior, somewhat concave margin, which is about two

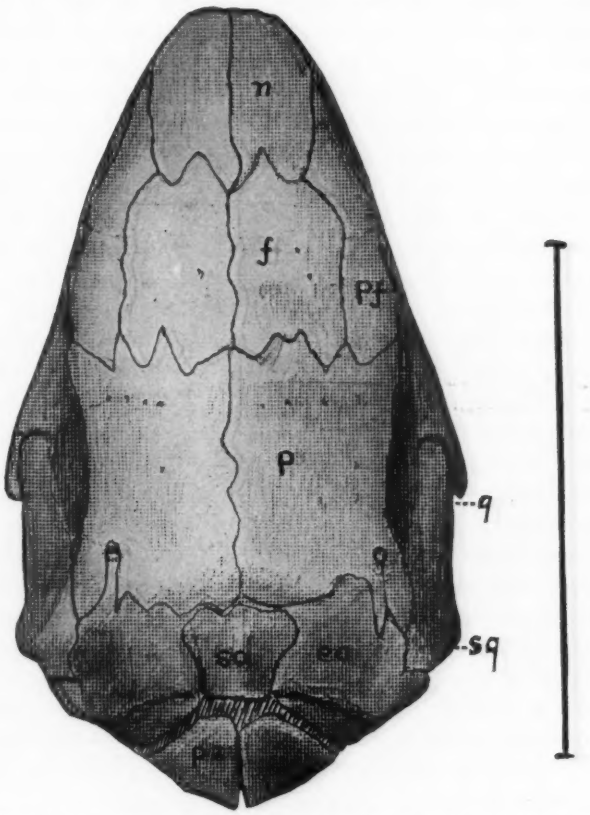

FIG. 2. *Lysorophus tricarinatus*, skull from above, enlarged five diameters. *n*, nasal; *f*, frontal; *pf*, prefrontal; *p*, parietal; *so*, supraoccipital; *eo*, epiotic; *pa*, proatlas.

fifths the length of the mandible; the teeth are directed somewhat obliquely outward.

The sides of the skull are in a nearly vertical plane, directed

somewhat obliquely outward posteriorly. The squamosal and quadrate, extending downward, forward and a little outward, meet the cotylus of the mandible a little back of the middle of the skull. Opposite the mandibular teeth in front are the narrow maxillæ, with teeth like those of the mandibles. They end freely and acuminately behind, and if connected at all with the bones of the upper part of the skull, the connection was small and slender and situated far forward. The whole side of the skull, from in front of the squamosal and quadrate seems to have been unossified; there are no jugals nor quadratojugals, and no temporal arches. The premaxillæ are also very slender, with four or five small teeth on each side. The position of the eyes was far forward, in the narrow space between the maxillæ and the prefrontals, and it is quite certain that these organs must have been very small. The nares also must have been minute and situated far forward, probably between the nasals and the premaxillæ near the middle line. Altogether, in life, save for its greater narrowness and more snake-like appearance the whole head must have been strikingly like that of *Necturus*.

Vertebræ. — The centrum is moderately elongated, deeply biconcave with persistent notochord, wholly without trace of hypocentra. In the middle below there is a median rounded keel, concave longitudinally, with a deep pit or fossa on each side reaching nearly to the internal cavity. On either side there is another, more slender carina, bounding the fossa above, with a more shallow concavity above it. The pedicel is elongate anteroposteriorly, the neural canal large. The centrum has no parapophysial facet or process for the rib. A little below and back of the anterior zygapophyses is the diapophysis, a flattened process directed anteriorly and a little downward, with the extremity thickened and a little rounded; they are short. The arches are depressed, a little convex in the middle anteroposteriorly, but without spine, the two sides separated by a persistent median suture, and the two bones are usually drawn somewhat apart, like the bones of the skull. The zygapophyses are rather large, flattened on their articular surface and are directed somewhat inwards or outwards. The ribs are large, flattened proximally, more cylindrical distally and are hollow. They have an

anterior angulation or curvature near the proximal third, this third being directed more obliquely backward. There are no traces of abdominal ribs in the numerous specimens examined, nor any of dermal plates, save in the case already spoken of, plates evidently belonging with a small mandible near them of an apparently different type from that of *Lysorophus*.

The terminal part of the tail, which is preserved in one speci-

FIG. 3. *Lysorophus tricarinatus*, skull from below, enlarged five diameters. *pm*, premaxilla; *m*, maxilla; *sq*, squamosal; *o*, otic fenestra; *oc*, occipital condyle; *pa*, proatlas.

men, ends rather gradually, tapering to a point. In the seventeen vertebræ of the series there are no ribs and no diapophyses, or very rudimentary ones anteriorly; and I can find no traces of chevrons. Characteristic figures of the vertebræ and ribs will be found in the cited papers of Case.

That *Lysorophus* is not a reptile requires no argument — the

unpaired supraoccipital, the absence of pineal foramen, quadratojugals, jugals, postfrontals, temporal arches, the evidently large parasphenoid, the double occipital condyles, paired branchials, neurocentral, single-headed ribs, etc., are positive evidence that the animal is not only not a reptile but that it is related to the modern urodele amphibians. In skull structure the characters are urodelan in every detail save the separated "epiotics," the intercalary of Cuvier, Vrolik and Cope, the paroccipital plates of Baur, the posttemporals of Broom; and this separation is precisely what would be expected in the early urodele. The exoccipitals otherwise seem to be a single bone in *Lysorophus*, but it is very probable that they are the result of an early fusion of the exoccipitals, paroccipitals and proötics. The squamosals and quadrates have the position and relations of modern salamanders, the quadrate rather better ossified than is usually the case. That the supraoccipital should be ossified is, also, what might be expected. The remarkable fact that this bone should be unpaired while all the remainder of the bones of the skull are very loosely joined, as also the fact that the corresponding element in the urodeles is cartilaginous would seem to preclude its identification with the paired supraoccipital plates, the postparietals of Broom, of the Stegocephalia, rather favoring Gaup's contention of the nature of his *tectum synoticum*.

The tricarinate structure of the vertebral centra is quite aberrant for a reptile, but not remarkable for a urodele; so also is the sutural division of the neurocentra, and, for the Permian, the neurocentral attachment of the single-headed ribs. The only aberrant character to distinguish *Lysorophus* from the Urodela is the long and rather broad ribs, unknown among these modern animals or their possible ancestors the Branchiosauria. It is, however, very evident that the earliest ancestors of both these groups must have long ribs, and their persistence in *Lysorophus* would be nothing remarkable. Nor do I think it impossible that *Lysorophus* and its immediate kin may have developed long ribs from the earlier short ones. Certain it is that this character alone, and it is the only aberrant one, should not exclude *Lysorophus* from the Urodela, though it may necessitate a slight revision in the definition of the group. That *Lysorophus* cannot

be classed with any of the divisions of the so-called Stegocephalia is quite as evident as its exclusion from the Reptilia; and upon the ribs alone the formation of a new order of Amphibia would not be at all justified.

That the genus represents a distinct family of the Urodela is of course obvious. Broili, under the erroneous supposition that it is a reptile of the order Rhynchocephalia gave to it the name Paterosauridæ, to indicate its "paternal" relationship with the reptiles. But this name was chosen in direct contravention of the rules of zoölogical nomenclature, since it is not represented by a genus in the group, and since any one is at entire liberty to apply the stem as a generic name in another group. The name is not tenable, and should be replaced by Lysorophidæ.

The condition in which the remains of so many of these animals are found, numerous series intermingled in vertical and lateral curves, is I think conclusive evidence that death overtook the creatures in the drying up of ponds and pools of water. That the animals were snake-like in life is of course proven by the long connected series of vertebræ of nearly uniform size. That they had but feeble power of sight is also assured by the very small size of the eyes. That they were perennibranchiate is I believe also extremely probable from the large size of the branchiæ, and the manner in which these creatures represented by their known remains met their death. Doubtless also they were bare skinned and more or less mud burrowing in habit. That *Lysophorus* stood in direct ancestral relationship to such forms as *Necturus* or *Proteus* is rather improbable, but that it was very close of kin to the ancestors of these forms I do believe to be very probable.

Salamander-Like Footprints from the Texas Red Beds. (Fig. 4.)

Recently, Miss Augusta Hasslock, of the Abilene, Texas, High School, has had the kindness to send me a number of thin red shales showing abundant markings of raindrops, worm or other tracks and footprints which must have been made by some salamander-like creatures of small size. The horizon is assumed to be Permian, but the fact that the shales occur not far below the

Cretaceous, inclines me to the belief that it will eventually be found to be Triassic. Enlarged photographs are given of some of the best of these numerous prints. The reverse of those at *a* and *b* are shown in a^1 and b^1. In the lower, left corner is shown the figure of a much larger print. It will be observed that the prints occur in pairs, one with clear evidence of five, the other with but four toes, from which the conclusion is justified that the crea-

FIG. 4. Footprints from the red beds of Texas, near Abilene, enlarged about one third.

tures were tetradactyl in front, pentadactyl behind, as were the Branchiosauria and as are the Urodela of to-day. Whether or not they were real salamanders which made the prints, or branchiosaurs, cannot be determined, but I am inclined to believe, in the light of the evidence presented by *Lysorophus*, that the origin of

some or all of these prints is due to real salamanders of modern type.

VENTRAL RIBS IN LABIDOSAURUS INCISIVUS. (Fig. 5.)

In a recent paper[1] I stated my belief that ventral ribs would eventually be found in some of the forms now classed in the rather heterogenous group known as the Cotylosauria, and I suspected that the specimen of *Labidosaurus* therein described presented such evidence, but could not be sure. This evidence has, however, been made clear by further preparation of that specimen. In the removal of the matrix from the under side of the pubes a small fenestra of accidental origin was found, and in this

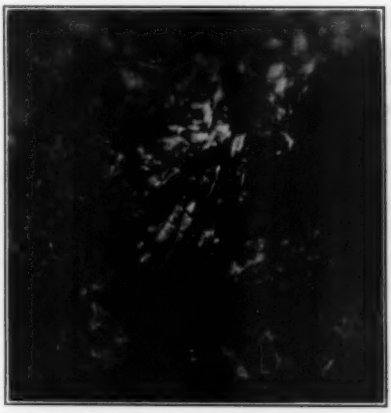

FIG. 5. Ventral ribs of *Labidosaurus incisivus*, enlarged about two diameters.

space, that is originally between the front end of the plate-like pubes and the vertebræ, are seen abundant evidences of small slender ribs, of some of which I give herewith a photographic illustration. At this spot seven ribs are seen lying closely together and parallel, directed from the anterior outer corner of the pubis inward and backward. Still further forward, and the continuation of these series, are further evidences of the same sort. The ribs are much smaller than I had expected to find them, but it is clear to me that the whole under side of the abdomen was enclosed in a closely set armor of slender ossified ribs. This char-

[1] *Journal of Geology*, XVI., p. 148, 1908.

acter adds another evidence of the relationship between the Procolophonia and *Labidosaurus*, and destroys its value as a group distinction.

Addenda. — Texas Permian Fields, September 25. Since the manuscript of the foregoing left my hands I have seen the recent paper by Case (Bull. Amer. Mus. Nat. Hist., xxiv, 531, June 30, 1908), in which he recognizes the amphibian nature of *Lysorophus*, figuring the skull with its exposed palate. He does not, however, discuss the relationship of the form and we differ in the interpretation of some of the bones.

Within the past week Mr. Miller, my assistant, has discovered two deposits of the species herein described from which cartloads of the peculiar nodules might be had for the digging. In two other places I have found them less abundantly. In examining the selected material, I have detected a small limb, very *Necturus*-like with four metapodials and epipodials in place, the mesopodials evidently unossified. It is of course possible, but not probable, that the limb is an accidental intrusion of some other small amphibian. My conviction is that the Lysorophidæ should be included in the Ichthyoidea.

FURTHER STUDIES ON THE ELIMINATION OF THE GREEN BODIES FROM THE ENDODERM CELLS OF HYDRA VIRIDIS.

D. D. WHITNEY.

In a recent paper I called attention to the fact that when green hydras are kept in a 0.5 per cent. solution of glycerine for several days they gradually lose their green color and become colorless.[1] The green bodies were observed to be thrown out of the enteric cavity through the mouth but it was not determined how they became separated from the endoderm cells in which they are contained. It was a matter of conjecture whether the endoderm cells became detached from the walls of the enteric cavity and carried the enclosed green bodies with them, subsequently disintegrating and liberating the green bodies in the enteric cavity, or whether the endoderm cells became ruptured and let their contents flow into the enteric cavity and then out through the mouth.

A microscopical study of the endoderm cells of both the normal green hydras and the green hydras that had been in a 0.5 per cent. solution of glycerine from one hour to about three weeks gave the following results:

In the normal hydras the endoderm cells are about as long as broad and each contains a large vacuole at its inner end. Nearly all of the green bodies are at the base of the cells. Figs. 1 and 2 show respectively in a cross and a longitudinal section the condition of the endoderm cells in green hydras that were starved for fourteen days in clear water. Several which were starved only thirty-six hours were sectioned but the endoderm cells did not differ noticeably from those in the green hydras that were starved for two weeks. The animals were allowed to remain without food in order that the endoderm cells, free from food, might be compared with those of animals that had been in the glycerine solutions for the same length of time without food.

[1] BIOLOGICAL BULLETIN, 1907, XIV.

When green hydras are put into the glycerine solution the endoderm cells become larger. As the cells are closely packed together their expansion laterally is prevented. Consequently becoming larger they push out into the enteric cavity, becoming several times as long as in the normal animals. Fig. 3 shows the condition of the endoderm cells of a green hydra that had been in the glycerine solution for one hour. Some of the cells are about twice the length of those in normal hydras but otherwise they seem to be similar.

In Fig. 4 the endoderm cells are much longer and more narrow than in the preceding case. This hydra had been in glycerine solution for three hours. In Fig. 5 the endoderm cells are about the same size as in Fig. 4 but the interior of the cells is filled with a very fine granular substance and the green bodies are scattered about in this substance especially in the distal two thirds of the cells. Very few green bodies were seen near the free end of the cells. This section was from a hydra that had been in the glycerine solution for sixty hours.

The condition of the endoderm cells of hydras that were rendered entirely colorless by being kept in the glycerine solution for eighteen days or more, Fig. 6, differs only from the endoderm cells of hydras that had been in the glycerine solution for sixty hours in having no green bodies in the cells.

Each endoderm cell doubles its size at least within an hour after being put into the glycerine solution as is seen in Fig. 3. As it remains longer in the solution it becomes extended until it is ruptured and owing to the pressure of the adjacent cells extrudes much of its contents into the enteric cavity. As soon as there is an equilibrium of pressure the rupture quickly heals or regenerates thus making the cell intact again. Soon after it is whole it swells again until it is ruptured a second time and discharges more of its contents, including the green bodies, into the enteric cavity. This process is repeated as long as the animal is kept in the glycerine solution and if kept too long until its death. By this repeated process of the rupturing of each endoderm cell and the discharge of its contents all the green bodies of each cell are finally eliminated and the cells remain colorless.

The green bodies have been seen being ejected through the

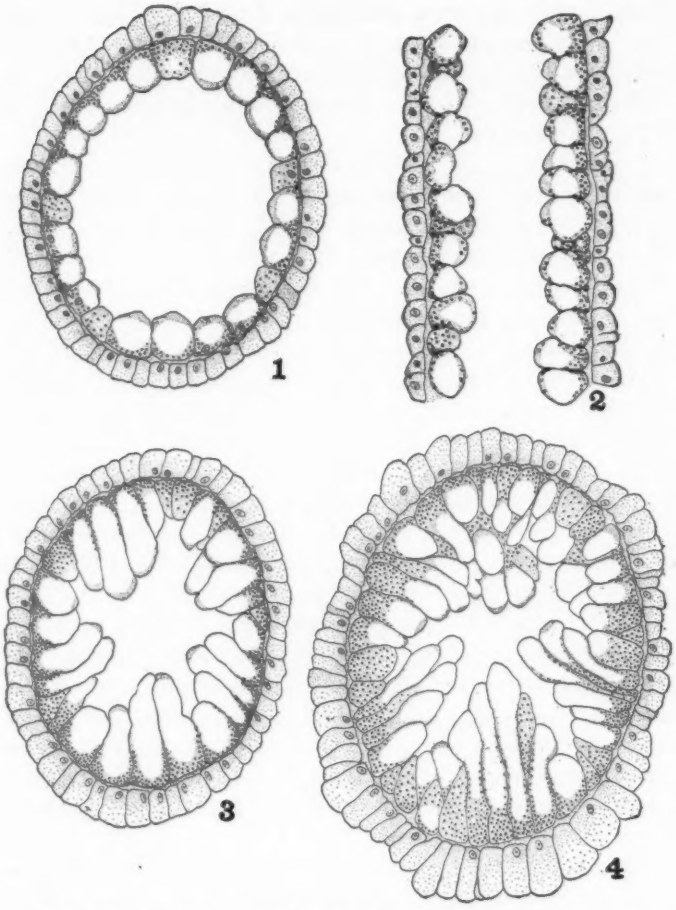

FIG. 1. Cross section of a green hydra that had been without food for 13 days.

FIG. 2. Longitudinal section of a green hydra that had been without food for 13 days.

FIG. 3. Cross section of a green hydra that had been without food for 36 hours and then put into a 0.5 per cent. glycerine solution for 1 hour.

FIG. 4. Cross section of a green hydra that had been without food for 36 hours and then put into a 0.5 per cent. glycerine solution for 3 hours.

mouth of living hydras which were in glycerine solution. They were also found in greater or less numbers in the enteric cavity

of the hydras that were sectioned and studied. They always seem to be free in the enteric cavity but sometimes they are mixed with a substance which resembles the granular contents of the endoderm cells. No free endoderm cells were ever seen in the enteric cavity.

Professor W. J. Gies was kind enough to perform some experiments for me in which blood corpuscles were put into a 0.5 per cent. solution of glycerine made with physiological salt solution. Upon measuring the diameters of the corpuscles both before and after putting them into the glycerine solution it was determined that if there was any change it was a slight shrinkage but never any enlargement of the corpuscles.

When these results of the effect of glycerine on blood corpuscles are compared with those obtained on the endoderm cells of hydras which were also kept in the same percentage of glycerine solution it is seen that the results are opposite — the corpuscles shrink and the endoderm cells become larger.

The shrinking of the corpuscles is probably due to an increase of the osmotic pressure of the solution caused by the addition of the glycerine and is purely a physical change.

The enlargement of the endoderm cells of hydras might be explained as due to the glycerine acting as a stimulus to the cell and causing certain vital processes in it to become active which result in a large and rapid absorption of water by each cell. The cells react to this stimulus as long as the animals are kept in the glycerine solution. Thus this change could be called a physiological one brought about by the stimulation of living processes in the cells.

Some cells were seen which had little protuberances or outpocketings on their inner free ends which looked as though they might be weak places in the cell wall that were forced out by the increasing pressure from within. Doubtless the ruptures occur at these places.

As it is a well-known fact that hydras have extraordinary powers of regeneration in the closing of wounds, as when their bodies are cut into two or more parts, and also in the replacing of lost parts, the assumption that the ruptured places in the endoderm cells close and grow together quickly is not, I think, an mprobable assumption.

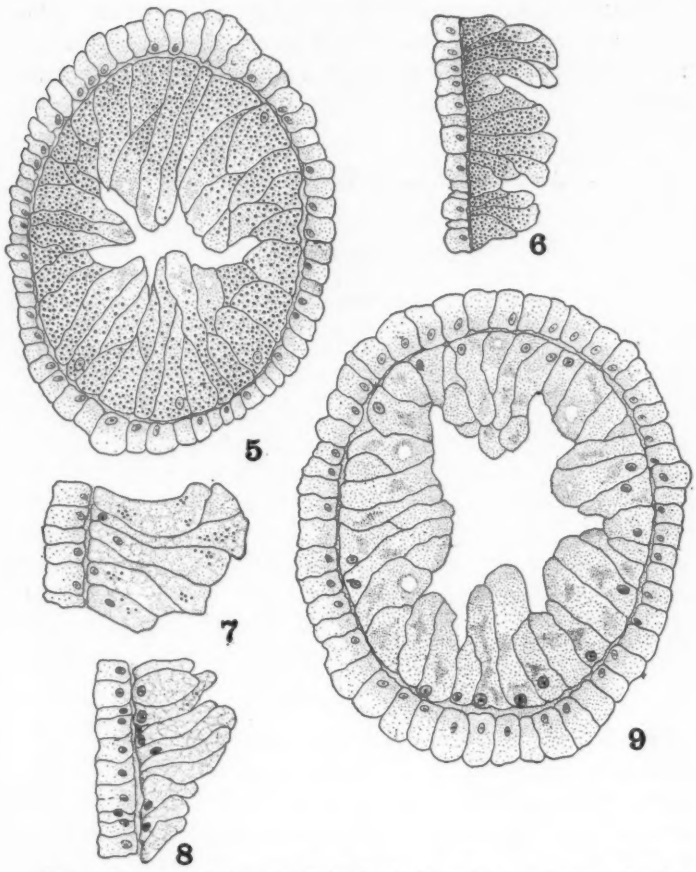

FIG. 5. Cross section of a green hydra that had been in a 0.5 per cent. glycerine solution for 60 hours.

FIG. 6. Portion of a longitudinal section of a green hydra that had been in the glycerine solution for 60 hours.

FIG. 7. Portion of a longitudinal section of a hydra that remained slightly green after being in a 0.5 per cent. glycerine solution for 13 days. Several groups of green bodies are seen in the endoderm cells.

FIG. 8. Portion of a longitudinal section of a hydra that was green when put into a 0.5 per cent. glycerine solution in which it remained 13 days and was rendered colorless. Only two green bodies seen in this section.

FIG. 9. Cross section of a hydra that was green when put into a 0.5 per cent. glycerine solution in which it remained 18 days and was rendered colorless. No green bodies are seen in this section.

Whatever the exact process may be it is certain that the endoderm cells remain in a greatly distended condition and lose all of their green bodies, many of which are found free in the enteric cavity.

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